International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 3, Jun 2019, 1785-1792


# THE MULTI OBJECTIVE OPTIMIZATION OF MECHANICAL PROPERTIES AND BEAD GEOMETRY IN MIG WELDING

**V. SANDHYA[1*], M. VAMSI KRISHNA[2], S. SAI KIRAN[2] & CH. SATISH[2]**

[1]*Assistant Professor, Department of Mechanical Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, India*

[2]*Students, Department of Mechanical Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, India*

***ABSTRACT***

***In this study the effect of input parameters on weld bead geometry and mechanical properties of the joint are analyzed to obtain the multi objective optimal conditions.***

***The experiment procedure are done by Design of experiments considering four parameters at three levels. Nine trials were done by varying the parameters arc voltage, welding current, gas flow rate, and root gap. The joints obtained are tested for bead geometry, hardness and ultimate tensile strength (UTS). The results obtained are analyzed using Taguchi and Grey relational analysis. By using the taguchi method it was found that the most significant parameter was welding current on the weld properties. The multi objective optimal weld process parameters for minimum bead width, minimum reinforcement and maximum penetration was obtained using grey relational analysis. The multi optimal condition for UTS and Hardness was predicted using grey relational analysis***

***KEYWORDS: Design of Experiments, Ultimate Tensile Strength, ANOVA, Grey Relational Analysis & Taguchi Method***

**Received**: Apr 20, 2019; **Accepted**: May 10, 2019; **Published**: Jun 21, 2019; **Paper Id.**: IJMPERDJUN2019191

Original Article

## INTRODUCTION

In most of the industries welding is applied for creating a permanent joint. Gas metal arc welding (or) metal inert gas welding (GMAW/MIG) is a progressive version of electric arc welding. In this method arc is created between a continuous coated electrode and work piece. In the literature many researchers have used MIG welding for welding at different positions and applied automation for increasing productivity. Due to these features we motivated to study the GMAW process in detail.

Ghazvinlo, H. R. *et al.*, reported that MIG welding was commonly used in automotive industry for joining of steel structural components. Monika K., *et al.*, investigated mechanical Properties of Dissimilar Joints using MIG Welding under the effect of speed of wire, voltage and welding current. In their experiment they used both joints (IS2062 & IS45C8) and (IS2062 & IS103Cr1) for the experiment. They found that when heat input increases the tensile strength decreases and when heat input decreases the metal hardness increases.

Aghakhani, M. *et al.*, explained work for increasing the quality and productivity of weldment using GMAW. They explained the influence of welding speed, voltage, flow rate of gas, feed rate on weld dilution. C. N. Patel *et al.*, evaluated weld bead hardness using MIG and TIG welding by altering the wire feed rate, wire diameter and welding current.

Bahar D. *et al.*, investigated the influence of process parameters in MIG welding to optimize the hardness and ultimate tensile strength (UTS) of a weld bead formed between dissimilar materials: mild steel (MS 1020) and stainless steel (SS 316) using Taguchi technique and Grey relational analysis.

Haragopal, G. *et al.*, reported influence of current, pre-heat temperature, groove angle and gas pressure on aluminium alloy (Al-65032), which is used for the construction of aerospace wings. Shekhar Srivastava *et al.*, developed mathematical model to maximize the depth of penetration, to minimize bead width and height by using Response Surface Methodology.

Nabendu Ghosh *et al.*, analysed the mechanical properties using Grey - Taguchi methodology by varying gas flow rate, current, electrode to plate distance on AISI 316L austenitic stainless steels. Visual inspection and radiographic test were conducted to analyze defects on surface and sub-surface. Kamal Pal *et al.*, used back propagation neural network (BPNN) for optimization of pulsed GMAW on low carbon steel.

In the present study we analyzed the impact of various parameters on strength and hardness of the weld joints. Optimization was done using grey relational analysis and taguchi method.

## EXPERIMENTAL PROCEDURE

MIG welding is widely used as it can be applied to different range of thickness and provides ease of operation and high productivity. However the prediction of the behavior of the weld joint is difficult as it influenced by no. of parameters. Mild steel is the cheapest and easily fabricated material used for a variety of different applications. It has very good strength and other structural properties for a variety of applications. Mild steel (MS) is used to carry out experiment and its chemical composition is shown in table 1.

**Table 1: Chemical Composition of the Material**

| Element | C | Mn | Fe | P | S |
|---|---|---|---|---|---|
| Weight% | 0.14-0.20 | 0.60-0.90 | 98.81-99.26 | 0.04 | 0.05 |

The MIG welding set up used for the experiment is shown in figure-1.

**Figure 1: Equipment Setup**

Sixteen Mild steel plates with dimensions 120x50x5mm$^3$ are prepared to study the experiment. To conduct the experiment electrode extension was placed at 10 mm and electrode to work distance was maintained at 20 mm

respectively. The welding was done by single pass. The electrode used is MS of 1.2 mm in diameter and coated with copper. Input parameters considered are arc voltage, current, flow rate of gas and root gap. The experimental procedure were developed using design of experiments using L16 orthogonal array considering three levels for each input parameter. The following table 2 gives the details of the Experiments carried out.

**Table 2: Design of Experiments using Various Parameters**

| S No. | Voltage (V) | Current (amp) | Gas Flow Rate (lit) | Root Gap (mm) |
|---|---|---|---|---|
| 1 | 22 | 150 | 5 | 0 |
| 2 | 22 | 200 | 8 | 1 |
| 3 | 22 | 250 | 12 | 2 |
| 4 | 24 | 150 | 12 | 1 |
| 5 | 24 | 200 | 5 | 2 |
| 6 | 24 | 250 | 8 | 0 |
| 7 | 27 | 150 | 8 | 2 |
| 8 | 27 | 200 | 12 | 0 |
| 9 | 27 | 250 | 5 | 1 |

The specimens after welding are shown in the following figure 2.

**Figure 2: Welded Specimens**

## TESTING

The universal test was done using ASTM A370-03a standards. The equipment used was a UTM Machine with a maximum capacity of 1000 KN. The specimen was prepared using the procedures given in ASTM A370-03a and typical dimensions are represented in below figure. (Figure-3)

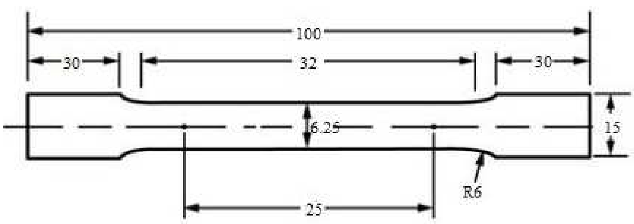


**Figure 3: Tensile Specimen Dimensions**

The experimental analysis was done by using ‘FIE’ Electronic Universal Testing machine (UTM), model TCS-2000. The experimental setup can be seen in figure 4.

The hardness test is carried by 1/16” ball intender and load of 150Kgs. The Rockwell hardness machine is shown in figure 5.


**Figure 4: Universal Testing Machine Figure 5: Hardness Testing Machine**

The work specimen after tensile test are shown in the figure 6.

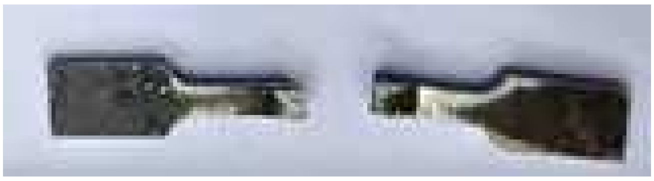

**Figure 6: Sample Specimen after Tensile Test**

## RESULTS AND DISCUSSIONS

The results obtained are tabulated in the table 3.

**Table 3: UTS and Hardness for each Specimen**

| Exp No. | Voltage (V) | Current (amp) | Gas Flow Rate (lt) | Root Gap (mm) | Tensile Strength ($N/mm^2$) | HRC |
|---|---|---|---|---|---|---|
| 1 | 22 | 150 | 5 | 0 | 272.356 | 59 |
| 2 | 22 | 200 | 8 | 1 | 459.243 | 52 |
| 3 | 22 | 250 | 12 | 2 | 299.363 | 53 |
| 4 | 24 | 150 | 12 | 1 | 315.779 | 56 |
| 5 | 24 | 200 | 5 | 2 | 392.776 | 78 |
| 6 | 24 | 250 | 8 | 0 | 141.345 | 61 |
| 7 | 27 | 150 | 8 | 2 | 358.686 | 63 |
| 8 | 27 | 200 | 12 | 0 | 324.316 | 78 |
| 9 | 27 | 250 | 5 | 1 | 288.76 | 56 |

The bead geometry of the nine specimens are listed in the following table 4

**Table 4: Bead Geometry Values**

| Exp No. | Depth of Penetration (mm) | Reinforcement (mm) | Width of the Weld (mm) |
|---|---|---|---|
| 1 | 2.5 | 3.5 | 12 |
| 2 | 2.5 | 4 | 13 |
| 3 | 3 | 2.5 | 12 |
| 4 | 2 | 2 | 15 |
| 5 | 2.5 | 2.5 | 13 |
| 6 | 2 | 3 | 14 |
| 7 | 2.5 | 2 | 11 |
| 8 | 2 | 2 | 12 |
| 9 | 3 | 3 | 13 |

**Grey Relational Analysis (GRA)**

This technique evaluates single performance characteristic from multiple performance characteristics. Data pre-processing is the first step to eliminate the problem of different units, targets and scales. The stepwise procedure followed in GRA process are

- Normalized the data between zero and one range.
- Calculate grey relational coefficients from normalized experimental data.
- For each characteristic Grey relational grade is computed by considering weighted averagegrey relational coefficients.
- Select the optimal parameters.

**Multi Response Optimization**

Grey relational analysis is employed in order to optimize the hardness as well as UTS. Grey relational coefficients (GRC), grey relational grades (GRG) and ranks are calculated to optimize the UTS and hardness which are shown in Table 5.

**Table 5: Grey Relational Coefficients, Grades and Ranks for UTS and Hardness**

| Exp no. | GRC (UTS) | GRC (HRC) | GRG | Rank |
|---|---|---|---|---|
| 1 | 0.460 | 0.650 | 0.555 | 6 |
| 2 | 1.000 | 1.000 | 1.000 | 1 |
| 3 | 0.433 | 0.929 | 0.681 | 2 |
| 4 | 0.526 | 0.765 | 0.645 | 3 |
| 5 | 0.705 | 0.333 | 0.519 | 7 |
| 6 | 0.333 | 0.591 | 0.462 | 8 |
| 7 | 0.613 | 0.542 | 0.577 | 5 |
| 8 | 0.541 | 0.333 | 0.437 | 9 |
| 9 | 0.482 | 0.765 | 0.624 | 4 |

GRA is performed to minimise bead width, reinforcement and maximize penetration which is shown in Table 6.

**Table 6: Grey Relational Coefficients, Grades and Ranks for Bead Geometry**

| Exp no. | GRC for Depth of Penetration(mm) | GRC for Reinforcement(mm) | GRC for Width of the Weld(mm) | Grade | Rank |
|---|---|---|---|---|---|
| 1 | 0.5 | 0.4 | 0.6667 | 0.1767 | 7 |
| 2 | 0.5 | 0.3333 | 0.5 | 0.1556 | 9 |
| 3 | 1 | 0.6667 | 0.6667 | 0.2778 | 1 |
| 4 | 0.5 | 1 | 0.3333 | 0.1833 | 5 |
| 5 | 0.5 | 0.6667 | 0.5 | 0.1778 | 6 |
| 6 | 0.5 | 0.5 | 0.4 | 0.1567 | 8 |
| 7 | 0.5 | 1 | 1 | 0.25 | 2 |
| 8 | 0.3333 | 1 | 0.6667 | 0.1889 | 4 |
| 9 | 1 | 0.5 | 0.5 | 0.25 | 2 |

Figure 7 Represents the main effect plot for S/N ratios and Table 7 Shows the response table for signal to noise of UTS.

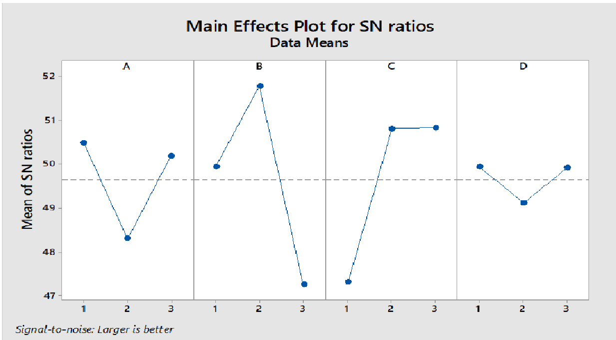


**Figure 7: Main Effect Plot for S/N Ratios of UTS**

**Table 7: Response Table for Signal to Noise Ratios of UTS**

| Level | Voltage | Current | Gas Flow Rate | Root gap |
|---|---|---|---|---|
| 1 | 50.49 | 49.93 | 47.31 | 49.93 |
| 2 | 48.29 | 51.78 | 50.81 | 49.11 |
| 3 | 50.17 | 47.25 | 50.83 | 49.91 |
| Delta | 2.20 | 4.53 | 3.52 | 0.82 |
| Rank | 3 | 1 | 2 | 4 |

Figure 8 shows the main effect plot for S/N ratios and Table 8 presents the response table for signal to noise of Hardness.

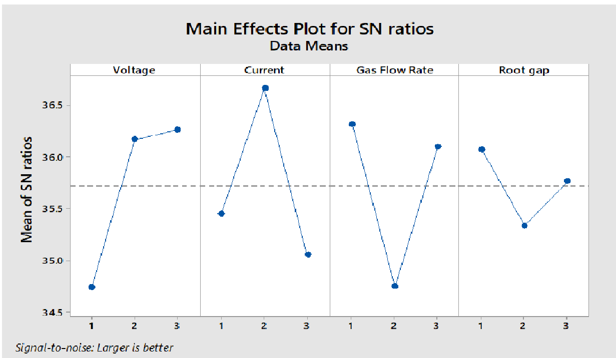


**Figure 8: Main Effect of S/N Ratio for Hardness**

**Table 8: Response Table for Signal to Noise Ratios of Hardness**

| Level | Voltage | Current | Gas Flow Rate | Root gap |
|---|---|---|---|---|
| 1 | 54.67 | 59.33 | 66.00 | 64.33 |
| 2 | 65.00 | 69.33 | 54.67 | 58.67 |
| 3 | 65.67 | 56.67 | 64.67 | 62.33 |
| Delta | 11.00 | 12.67 | 11.33 | 5.67 |
| Rank | 3 | 1 | 2 | 4 |

## CONCLUSIONS

Butt weld joints obtained by Metal Inert Gas welding were analyzed using multi objective optimization for bead geometry and mechanical properties. The optimal weld process parameters for minimum bead width, minimum reinforcement and maximum penetration was obtained using grey relational analysis as experiment no 3. Whereas the optimality for ultimate tensile strength and hardness was obtained from the experiment no 2 process parameters. The response table shows that welding current influences UTS and hardness properties of the weld bead.

### *REFERENCES*


1. *Rizvi, S. A., Tewari, S. P., Wajahat, A.: A text book of Advanced Welding Technology, Kataria & Sons (P) Ltd., New Delhi 2009.*
2. *Ghazvinlo, H. R., Honarbakhsh, A., Shadfar, N.: Effect of Arc Voltage, Welding Current and Welding Speed on Fatigue Life, Impact Energy and Bead Penetration of AA6061 joints Produced by robotic MIG Welding, Indian Journal of Science and Technology, 3(2), 2010.*
3. *Monika K., Bala Chennaiah M., Nanda Kumar P. and Prahalada Rao P., "The Effect of Heat input on the Mechanical Properties of MIG Welded Dissimilar Joints". International Journal of Engineering Research & Technology,(2013), vol2, pp. 1406-1413.*
4. *Rathod, C. H. A. N. D. A. R., & Reddy, G. K. (2016). Experimental investigation of angular distortion and transverse shrinkage in CO2 arc welding process. International Journal of Mechanical Engineering, 5(4), 21-28.*
5. *M. Aghakhani, E. Mehrdad, and E. Hayati, "Parametric optimization of gas metal arc welding process by Taguchi method on weld dilution, "International Journal of Modeling and Optimization, August (2011), Vol.1, No. 3, pp.-216-220*
6. *D. Bahar, Md. Nawaz Sharif, K. Shravan Kumar and D. Reddy, " Optimization of MIG welding process parameters for hardness and strength of welded joint using Grey relational analysis". International Journal of Research in Advent Technology, Vol.6, No.5, May 2018*
7. *Zarmai, M. T., Ekere, N. N., Oduoza, C. F., & Amalu, E. H. (2015). Effect of intermetallic compounds on thermo-mechanical reliability of lead-free solder joints in solar cell assembly.*
8. *G. Haragopal, P V R Ravindra Reddy, G Chandra Mohan Reddy and J V Subrahmanyam, "Parametric design for MIG welding of Al-65032 alloy using Taguchi Technique", Journal of Scientific and Industrial Research, Vol. 70, October 2011, pp.844-858.*
9. *Shekhar Srivastava**, R. K. Garg, "Process parameter optimization of gas metal arc weld***ing on IS:2062 mild steel using*** *response surface methodology", Journal of Manufacturing Processes, Volume 25, January 2017, Pages 296-305*
10. *Nabendu Ghosh, Pradip Kumar Pal, Goutam Nandi, "Parametric Optimization of MIG Welding on 316L Austenitic Stainless Steel by Grey-based Taguchi Method", Procedia Technology, Volume 25, 2016, Pages 1038-1048*

11. *David, D. C. N., Stephen, S. E. A., & Ajoy, J. A. (2016). Cost minimization of welded beam design problem using PSO, SA, PS, GOLDLIKE, CUCKOO, FF, FP, ALO, GSA and MVO. Int. J. Appl. Math, 5, 1-14.*

12. *Kamal Pal, Surjya K. Pal, "Multi-objective Optimization of Pulsed Gas Metal Arc Welding Process Using Neuro NSGA-II", Journal of The Institution of Engineers (India): Series C, 2018, pp 1–10*

13. *P. K. Palani , N. Murugan, "Selection of parameters of pulsed current gas metal arc welding", Journal of Materials Processing Technology, Volume 172, Issue 1, 20 February 2006, Pages 1-10*